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Richard S. Jensen
Christopher D. Wickens
Reuben L. Hann PhD.
David P. Harding

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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2261 Monahan Way, Bldg. 196
WPAFB OH> 45433-7022

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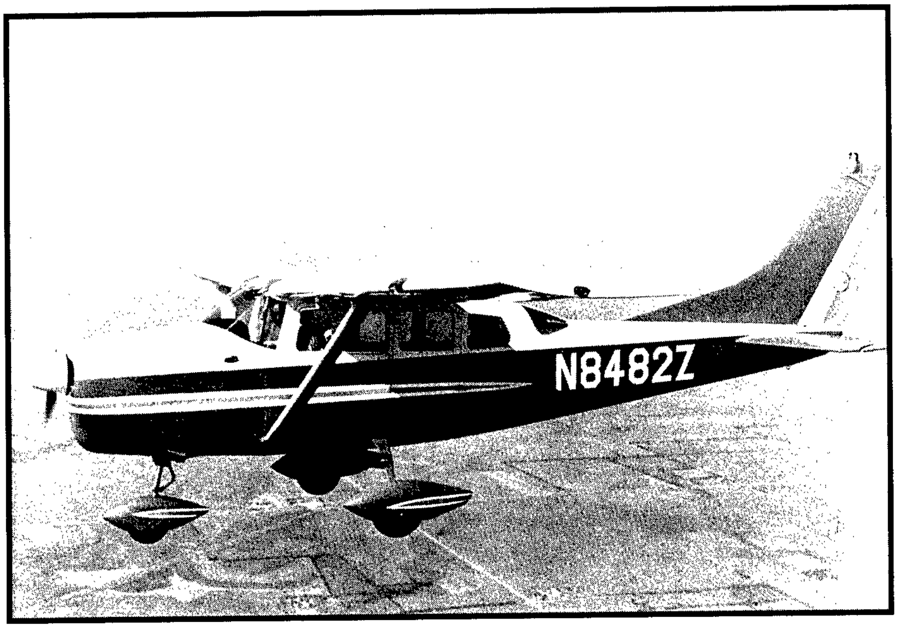
VOLUME III: NUMBER 5 (1992)

CSERIAC GATEWAY

PUBLISHED BY THE CREW SYSTEM ERGONOMICS INFORMATION ANALYSIS CENTER

In this issue:

CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Alexandria, VA, managed by the Armstrong Laboratory, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.



The 1964 Cessna 205. Photo courtesy of Jim Cavanagh, Aircraft Owner Organization.

Do Pilots Need Human Factors Training?

Richard S. Jensen

Several years ago, the importance of judgment in aviation was made clear to me, when I was a new hire and my boss and I flew a Cessna 205 (see fig.) with a load of passengers from the USA midwest to Colorado for a meeting at the Air Force Academy during the early spring. After landing for fuel in Kansas, we prepared for our final leg to Colorado Springs where the weather was "Sky obscured, 1/4 mile visibility" and forecast to remain the same for the rest of the day. At my boss's suggestion, we filed for Colorado Springs, with Denver Arapaho Airport (weather, "clear") as the alternate. During this leg, my boss (flying in the right seat) was on the radio from time to time asking for updates on the weather at Colorado Springs. "Has anyone landed there today?" "No," was the reply, "One Lear tried earlier in the day but missed." Despite this, he kept asking me to consider going to Colorado Springs (This was before the Federal Aviation Regulation [FAR] making it illegal to attempt an approach when the weather was below minimums). As we approached Denver (we could actually see Arapaho Airport) he said, "Let's go to Colorado Springs and give it a try!"

I thought about the situation we would face on a minimums approach into Colorado Springs. I could see him trying to press me (I was flying in the left seat.) to go "a little lower" and arguing with me about whether we could see anything on the ground

Continued on page 2

while trying to maintain glideslope and localizer approaching 200 feet from the ground! He was making me feel "chicken." Fortunately, at this point, my better judgment took over and I said, "No, we're going to Arapaho!" and I took the radio, asked for the clearance, and landed at Arapaho Airport. He did not say anything the rest of the way, and on the return trip I was given the seat in the rear.

Until recently, pilot training has remained much the same since the Wright brothers. The emphasis has always been on teaching the technical skills of manipulating the airplane safely. In the last ten years many have recognized that advances in automation and cockpit technology have changed the role of the pilot, and a strong emphasis on human factors is emerging. Our awareness of the "human error problem" in aviation began when cockpit voice recordings of pilot communications prior to fatal accidents revealed the enormous factor played by human error in accidents. Accident statistics still show that over 80 percent of general aviation accidents are related to human factors (65 percent of airline accidents), and over half of these are due to faulty pilot judgment. Now the International Civil Aviation Organization (ICAO) has mandated human factors training for pilots of its member countries (ICAO, 1989). Many countries are now including human factors training as required curriculum in pilot training courses and pilot examinations (e.g., Canada and England). In the U.S., human factors training is not mandatory, but the Federal Aviation Administration's (FAA) Advanced Qualification Program (AQP) initiative provides an incentive for airlines to develop and teach crew resource management (CRM) to pilots. Many of the most advanced flight training programs taught at the university level have added human factors training to the curriculum (see Trollip & Jensen, 1991). Pilot judgment (or aeronautical decision making, the FAA's preferred term) is one aspect of human factors training that is gaining importance in the best flight training programs.

Pilot Error

To understand the problem of aviation judgment we must first look at human error. Pilots have long been dismayed by the use of the term "pilot error" to describe their failures, because it sounds as if the pilot were negligent in some way. In most circumstances resulting in pilot error accidents, the pilots involved were putting forth their best efforts to fly safely. To say that an accident was caused by pilot error and go no further is no better than to say that a mechanical failure accident was caused by the airplane. In both cases we are obliged to look further into the reasons for the pilot or mechanical failure that led to the accident. Obviously, mechanical failures are easier to trace because there is usually an abundance of physical evidence to show the way. The reasons for pilot failures are more difficult to discover, but they usually can be found as well, if one is willing to use psychological and sociological expertise and probe into the behavior and thought patterns of the crew involved.

In continuous controlled flying we are always comparing intended or desired outcome with actual outcome to know what to do with the controls. As these two outcomes depart from one another, we notice them, make decisions, and act by moving the controls to bring the two closer together. In fact, straight and level flight can be defined as a series of *error* correction maneuvers. *To err is human*; to correct errors is what flying is about. However, it is much easier for pilots to accept that they make control errors than to accept their judgmental errors.

Judgment Definition

There is a certain truth to the popular belief that judgment is simply "common sense" applied to making decisions. "Sense" implies knowledge and intense awareness, realization, and understanding of all the factors involved in making a decision. Sense is generally seen as a person's ability to act effectively and positively in any given situation. "Common" refers to the fact that societal needs and wishes are known and applied to the decision.

A popular conception of judgment is that it is identified as equivalent to the outcome. "If the decision outcome was positive it was 'good judgment,' and if it turned out badly, it was 'bad judgment.'" This restatement of "The end justifies the means" is clearly wrong in my view of aviation judgment. Judgment is not an end, but a *process* for achieving an end. Aviation judgment is the *mental process* used to formulate aviation decisions. The decision is the final stage of this mental process. As important as outcome is to aviation, its only part in the judgment process is to provide feedback to help us learn more for the next decision.

To further clarify our terms, it is important to distinguish between perceptual and cognitive judgment. Pilots are constantly making decisions based on their visual perceptions. For example, they judge distance, clearance, altitude, closure rate, and speed. These perceptual judgments are highly important to the pilot's task of controlling the aircraft. However, they do not require much thought and are relatively easy to learn and to perform consistently, particularly when the pilot is aware of the anomalies and illusions that can occur. Our concern here is with more complex forms that we refer to as "cognitive" judgment. In comparison with perceptual judgment, the characteristics of cognitive judgment are 1) the information available is more uncertain, 2) the pilot usually has more time to think, 3) there are usually more than two alternatives, 4) the risks associated with each alternative are harder to assess, and 5) the final decision is more easily influenced by non-flight, background factors such as stress, fatigue, financial pressure, and personal commitment.

To understand how one can improve aviation judgment, it is helpful to look at a judgment model with two parts. The first part, called *rational judgment*, relates to intellectual abili-

ties or discriminability. The second part, called *motivational judgment*, relates to motivation or bias. These are defined in the table.

Rational Judgment

The first part of good pilot judgment is the mental ability of the pilot to detect, recognize, and diagnose problems, to establish available alternatives, and to determine the risk associated with each alternative. This part is purely rational, and if it could be used alone (which is not possible), would allow problem solving using mathematical functions in much the same manner as a computer. This does not mean it would be error free; it uses information that is probabilistic and, therefore, predicts outcomes that are not certain. In addition, rational judgment depends upon the amount, type, and accuracy of the information stored in the pilot's memory as well as his or her learned capabilities to retrieve and process information. To optimize rational judgment requires high levels of knowledge, experience, organized mental structures, and systematic computational and problem-solving abilities.

Motivational Judgment

The second part is the motivational or bias aspect of judgment. The emphasis is on the directional rather than the aspects of motivation dealing with intensity. This part of judgment says that humans (and pilots) base their decisions, in part, upon bias factors or tendencies to use less than purely rational (as defined by society) information. These factors include immediate gratification such as ego, adventure, commitment, duty, social pressure, and emotional arousal in the form of worry, fear, stress, anxiety, and euphoria, as well as more long-term biases such as risk-taking attitudes, and personality factors (e.g., fear of failure and defensiveness). Optimizing motivational judgment requires both 1) an awareness of biasing factors and 2) a will (motivation) to suppress these error-producing factors so that decisions can be made on the basis of relevant safety factors from the physical world.

Training Methods

The best way to learn judgment is to discover it from the experiences of others. Although experience is a great teacher, in aviation the experience of others is safer. It is important to realize that good decision-making skills, like any other skill required in flying airplanes, can be learned more quickly and more safely through a systematic training program than through the traditional "trial-and-error" method. So, we suggest the use of not only your own experiences but also those of others to develop your own flying judgment.

At this time, the rational aspect of pilot judgment has received very little attention. However, there is much in the literature outside of aviation, including stock brokers, livestock judges, and medical diagnosticians, indicating that this aspect of judgment can be taught. In each of the areas studied, judgmental training occurs over a fairly long apprenticeship program in which the trainee observes the expert make decisions and learns by observation. Bill Rouse and his colleagues have performed a series of experiments to develop fault diagnosis training systems to be administered on computer (Rouse, 1979). One demonstration study at Ohio State (Jensen, Adrion, & Maresh, 1986) has shown the effectiveness of the DECIDE model in teaching rational judgment to pilots.

On the other hand, the motivational aspect of pilot judgment has received the bulk of research. Studies around the world have shown that motivational training can be very effective. The model used in all these studies may be called the Attitude Model or Five Hazardous Attitudes: Anti-Authority, Impulsivity, Invulnerability, Macho, and Resignation. An awareness of these attitudes, that are found to some extent in everyone, can help to develop a more positive and rational approach toward flying decisions.

The most important aspect of the teaching philosophy is to understand that you cannot force people to behave correctly every time, but that if people are aware of the factors that influence their decision making, they will act closer to what society expects, which is closer to safety. The teaching method consists of showing students how others have found themselves in trouble in

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The Judgment Model

GOOD PILOT JUDGMENT IS:

Part I: Rational Judgment

The ability to discover and establish the relevance of all available information relating to problems of flight, to diagnose these problems, to specify alternative courses of action, and to assess the risk associated with each alternative.

AND

Part II: Motivational Judgment

The motivation to choose and execute a suitable course of action within the available time frame.

Where:

a. The choice could be either action or no action and
b. "Suitable" is a choice consistent with "societal" norms.

various situations. The method known as "situational teaching" offers actual incident and accident scenarios that show how other pilots have been influenced by the five hazardous attitudes. Exercises to develop understanding and recognition of the hazardous attitudes are used, and ways to break the chain of poor decisions that often lead to accidents are offered. Some of the training is done in the classroom. The rest is offered in simulators and in flight. At least one program has been developed by Roy Fox at Bell Helicopter to teach these concepts on computer. We are now preparing a book to be published in 1993 by Ashgate for use in teaching pilot judgment.

Research and Operational Results

Studies in the USA, in Canada, and in Australia have demonstrated that motivational judgment can be taught effectively, at least in the short term. In each case pilots who had been taught judgment using this model performed judgment tasks better than those who received conventional training. The rates of improvement as judged by observers in test flights with students following the training have varied from 16 percent to nearly 50 percent.

An even more exciting result has been provided by two helicopter operational training studies. Petroleum Helicopter Inc. (PHI) and Bell Helicopter have both offered the attitude method of judgment training to large numbers of helicopter pilots. PHI has reported a 54-percent reduction in accidents after giving this training to their pilots. Bell Helicopter in two studies reported a 36-percent decrease and a 48-percent decrease in accident rates after the training. Both organizations point to the judgment training as the most important tool now available to improve safety in helicopter flying.

OSU Aviation Education

Clearly, human factors education and judgment training, in particular, are where the emphasis should now be placed in pilot training. Technical skills are still needed but as we move into more automated cockpits, decision-making skills need higher priority in training. The Ohio State University (OSU) is one of several universities that have recognized the need for this change in aviation education. OSU has taken a leadership role in the development of new programs to teach these skills. A new building has recently been completed on the OSU campus to house the Aviation Program which includes three degrees, in engineering, arts and sciences, and business.

The OSU Aviation-sponsored Biennial International Symposium on Aviation Psychology has been a major force behind a recognition by the whole of the international aviation community for human factors training for pilots. Strong emphases have been seen in the areas of cockpit design, crew resource management, and judgment training in these programs. The next Symposium (the seventh) will be held April 26-29, 1993 in Columbus, Ohio. Workshops, paper sessions, discussion sessions, and aviation human factors trade exhibits mark this event. Attendance is expected from all parts of the aviation community in the USA and at least 30 other countries. For more information please contact Prof. Richard S. Jensen (614-292-8378). Associated with the Symposium is the quarterly *International Journal of Aviation Psychology*, published by Lawrence Erlbaum Associates, which seeks to provide an education for pilots through an application of academic, government, and industrial aviation human factors research. ●

Richard Jensen, Ph.D., is an Associate Professor of Aviation, Associate Professor of Industrial and Systems Engineering, and Director of the Aviation Psychology Laboratory, The Ohio State University, Columbus, OH.

References

International Civil Aviation Organization (1989). *Training of Operational Personnel in Human Factors* (8th Ed.). Montreal, Canada: Transport Canada.

Jensen, R. S., Adrion, J., & Maresh, J. (1986). *A preliminary investigation of the application of the DECIDE model to aeronautical decision making.* Columbus, OH: OSU Aviation Psychology Laboratory.

Rouse, W. B. (1979). Problem solving performance of maintenance trainees in a fault diagnosis task. *Human Factors, 21*, 195-203.

Trollip, S. R., & Jensen, R. S. (1991). *Human factors for general aviation.* Englewood, CO: Jeppesen Sanderson.

COTR Speaks

Reuben L. Hann

Since the last *Gateway* there have been some personnel changes at CSERIAC. It was with mixed feelings that we said goodbye to Dr. Ron Schopper, our Chief of Technical Services and Analyses. We were unhappy to lose a good friend and capable staff member, but pleased that Ron was moving on to an important and challenging position with the National Institute of Occupational Safety and Health. We wish him all the best in his new position. At the same time we are pleased to announce a new face on the CSERIAC staff. Joining us is Dr. Paul DiTullio, who will be serving as Marketing and Technology Transfer Manager. Paul has the important task of spreading the word about CSERIAC and its unique services and products. Technology transfer is an important part of the CSERIAC mission. To maximize return on investment, technology developed at taxpayer expense must be transitioned to other DoD and industrial users. Paul will be working to uncover these hidden "gems," and will help the developers to package and promote the results of their labors, for the benefit of the entire ergonomics community.

Dr. Richard Jensen from The Ohio State University (OSU) leads off this edition with our feature article "Do Pilots Need Human Factors Training?" He begins by relating an aircraft "incident" which could have become an aircraft "accident," had he taken the advice of his co-pilot. He discusses pilot error and judgment, and proposes a model of judgment and its implications for training methods. He then makes a comparison between

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Calendar

January 10, 1993
Washington, DC, USA
26th Annual Workshop on Human Factors in Transportation, organized by the Transportation Research Board, National Research Council, at the Sheraton Washington Hotel. Contact Richard Pain, Transportation Research Board, 2101 Constitution Ave., NW, Washington, DC 20418; (202) 334-2960, (202) 334-2003.

March 1-5, 1993
Orlando, FL, USA
9th IEEE Conference on Artificial Intelligence Applications, at the Disney World Hilton. Contact CAIA-93, IEEE Computer Society, 1730 Massachusetts Ave., NW, Washington, DC 20036-1903; (202) 371-1013.

March 17-20, 1993
Los Angeles, CA, USA
Technology and Persons with Disabilities, sponsored by California State University, Northridge, Office of Disabled Student Services, at the Los Angeles Airport Marriott Hotel. Contact Harry J. Murphy, Office of Disabled Student Services, CSUN, 18111 Nordhoff St. - DVSS, Northridge, CA 91330; (818) 885-2578, fax (818) 885-4929, Email: HMURPHY@VAX.CSUN.EDU.

March 31- April 4, 1993
Chicago, IL, USA
EDRA 24, 24th Annual Meeting of the Environmental Design Research Association, "Power by Design," at the Allerton Hotel. Contact EDRA Business Office, P.O. Box 24083, Oklahoma City, OK 73124; (405) 843-4863.

April 13-16, 1993
Edinburgh, UK
Ergonomics Society Annual Conference "Ergonomics - For Industry," at Heriot Watt University. Contact Conference Manager, Ergonomics Society, Devonshire House, Devonshire Square, Loughborough, Leichester LE11 3DW, UK; (44) 509-234904. *Abstract deadline: October 2, 1992.*

April 18-21, 1993
Oak Ridge, TN, USA
American Nuclear Society meeting, "Nuclear Plant Instrumentation, Control, and Man-Machine Interface Technologies," cosponsored by the Human Factors Division of the ANS, the HFS Smoky Mountain Chapter, and others. Contact Bill Knee or Jim White, Oak Ridge National Laboratory, P. O. Box 2008, Oak Ridge, TN 37831-6360; (615) 574-6163 (Knee), (615) 574-5592 (White), fax (615) 574-9619. *Summary deadline: August 1, 1992.*

April 26-29, 1993
Knoxville, TN, USA
5th Topical Meeting on Robotics and Remote Handling, sponsored by the American Nuclear Society, Oak Ridge/Knoxville Section, and the ANS Remote Systems Technology Division, at the Holiday Inn World's Fair and Exhibition Center. Contact the Topical Meeting on Robotics and Remote Handling, P.O. Box 200001, Oak Ridge, TN 37831, or Norbert Grant, (615) 574-4530, fax (615) 574-4624. *Abstract deadline: July 1, 1992.*

May 24-27, 1993
Utica, NY, USA
3rd Annual "DUAL-USE Technologies and Applications Conference," hosted by the SUNY Institute of Technology at Utica/Rome and sponsored by the IEEE Mohawk Valley Section. Contact John Salerno, College Relations Office, SUNY Institute of Technology at Utica/Rome, P.O. Box 3050, Utica, NY 13504-3050; (315) 792-7113, fax (315) 792-7143.

June 14-18, 1993
Warsaw, Poland
International Ergonomics Association World Conference '93, "Ergonomics of Materials Handling," organized by the IEA Industrial Ergonomics Technical Group of the Science and Technology Committee. Contact W. Karwowski, General Conference Chair, Center for Industrial Ergonomics, University of Louisville, Louisville, KY 40292; (502) 588-7173, fax (502) 588-7397, Email: wokarwo@-ulkyvm.bitnet. *Proposal deadline: August 15, 1992.*

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, CSERIAC Program Office, AL/CFH/CSERIAC, Wright-Patterson AFB, OH 45433-6573

conventional training methods and a newer approach which incorporates changes recommended from the proposed model. Finally, he describes aviation education at OSU and gives notice of the upcoming Aviation Psychology Symposium April 26-29, 1993. This important symposium is sponsored by OSU and held in Columbus, OH.

The fifth speaker in the Armstrong Laboratory Colloquium Series was Dr. Christopher Wickens, who spoke about "Computational Models of Human Performance." Chief of Technical Services and Analyses, Dr. Ron Schopper has prepared a synopsis of this presentation. Dr. Wickens discusses computational modeling in terms of workload prediction and display layout. I had an opportunity to discuss various aspects of his work and get his opinions on some general ergonomics issues with Chris while he was at Armstrong Laboratory. You will find a selected portion of our conversation following the synopsis.

The final article in this issue of *Gateway* describes the software program JACK. It was originally developed as a realistic, computer-based human model for the simulation of human performance in enclosed spaces. However, because of its flexible nature, it has found many other useful applications. David Harding, JACK Product Manager for the University of Pennsylvania's Center for Technology Transfer, describes some of these applications, its useful features, and how it can be obtained.

All of us at CSERIAC hope you had a rewarding and successful 1992, and look forward to the opportunity to assist you with our full range of ergonomics information products and services during 1993. ●

Reuben "Lew" Hann, Ph.D., is the Contracting Officer's Technical Representative (COTR) who serves as the Government Technical Manager for the CSERIAC Program.

Announcements

Online Searching with DGIS and SearchMAESTRO

With hundreds of online databases available, each with its own logon procedure and search language, finding and processing needed information can be overwhelming. The Defense Technical Information Center (DTIC) is offering two systems to help with such online searching.

The Department of Defense Gateway Information System (DGIS) provides access to 20 different online systems with more than 900 different databases. By supplying DTIC with personal account information, DGIS automatically dials and logs onto the selected online system. DGIS can search more than one database at a time, and includes powerful post-processing tools that allow users to reformat and analyze citations in many ways. These features include the elimination of duplicate citations, the ability to merge multiple files into one, sort citations by almost any field, analyze citations, and cross correlate fields. DGIS will arrange citations from BRS, DIALOG, DROLS, NASA/RECON, and ORBIT into the format specified by the user. In addition, DGIS provides access to an electronic mail module through the Internet and DDN system.

SearchMAESTRO (Menu-Aided Easy Searching Through Relevant Options) is designed to help novice users conduct their own online database research. End users may easily access 13 different online systems with more than 850 total databases by using this menu-driven system. SearchMAESTRO will even select the appropriate database for a given search strategy if one is not otherwise indicated. In addition, there is no need for separate accounts with each database vendor; even if the user searches all 850 databases available to SearchMAESTRO, there is only one bill.

For more information call Ms. Patricia Tillery on (703) 274-6434 or DSN 284-6434 or write to:

Defense Technical Information Center
DGIS/SearchMAESTRO Information
Cameron Station, Building 5
Alexandria, VA 22304-6145

Certification for Ergonomists and Human Factors Professionals

The Board of Certification in Professional Ergonomics is now accepting applications for professional certification of ergonomics and human factors practitioners. Applicants should have a mastery of ergonomics knowledge and methods, as well as expertise in the analysis, design, and evaluation of products, systems, and environments for human use. Qualified applicants may choose to be certified as either Certified Professional Ergonomists (CPE) or as Certified Human Factors Professionals (CHFP). Applications are available from:

Board of Certification in Professional Ergonomics
Office of the Executive Director
P. O. Box 2811
Bellingham, WA 98227-2811 USA
phone: (206) 671-7601 fax: (206) 671-7681

Minimum qualifications are an MA/MS or equivalent in ergonomics or a closely related field and 7 years of demonstrable experience in the practice of ergonomics. Applications are open to ergonomists internationally.

Certification will be based on an evaluation of work samples and supporting documentation through December 31, 1993. The application processing fee is US$200 (nonrefundable) with an annual renewal fee of $75. After December 31, 1993, applicants will be required to pass a written examination.

The Board of Certification in Professional Ergonomics was formed as a nonprofit corporation in 1990. Although the Board was established with support from the Human Factors Society, it is independent of any professional, scientific, or trade association.

Current members of the Board are Alphonse Chapanis, Ph.D; David Meister, Ph.D.; Melvin H. Rudov, Ph.D.; Hal W. Hendrick, Ph.D.; George A. Peters, J. D.; H. Harvey Cohen, Ph.D.; David J. Cochran, Ph.D.; Jerry R. Duncan, Ph.D.; Steven M. Casey, Ph.D. The Executive Director is Dieter W. Jahns, M.S.

Human Factors Society Fellows Elected

Four distinguished nominees were recently elected Fellows of the Human Factors Society. They are:

Diane L. Damos, Associate Professor, Institute of Safety and Systems Management, University of Southern California, Los Angeles, CA.

Arthur D. Fisk, Associate Professor and Coordinator, Engineering Psychology Division, School of Psychology, Georgia Institute of Technology, Atlanta, GA.

Anil Mital, Associate Professor of Engineering and Director, Ergonomics and Engineering Controls Laboratory, University of Cincinnati, OH.

Richard A. Olsen, independent consultant and expert witness, Santa Clara, CA.

These distinguished professionals join the Society's other 212 Fellows. Fellow status requires a minimum of 5 years of membership, 10 years of professional experience in the field, outstanding and demonstrable contributions to human factors, 3 year's direction or supervision of significant human factors efforts, and at least one year's service to the Society.

Industrial Ergonomics Bibliography

The Human Factors Society has revised its guide to the literature on industrial ergonomics, "Industrial Ergonomics Bibliography." The new brochure is free of charge and lists publications that contain data useful for the design of jobs in industry.

The bibliography is divided into six sections, in addition to lists of periodicals and proceedings: *General* lists texts and handbooks; *Worker Characteristics* covers size, strength, age, and gender; *Job Design* addresses productivity, human error, fatigue, and accidents; *Equipment Design* concerns displays, controls, and tools; *Workplace Design* includes information on chairs, benches, floors, and stairs; and *Environmental Design* covers heat, noise, vibration, and illumination.

The bibliography is designed for human fac-

tors practitioners, industrial engineers, safety professionals, occupational physicians and nurses, industrial hygienists, personnel specialists, managers, labor union officials, and workers.

To obtain a free copy of the "Industrial Ergonomics Bibliography," contact the Human Factors Society, P.O. Box 1369, Santa Monica, CA 90406-1369; (310) 394-1811, fax (310) 394-2410.

Liveware Survey & Database Progress

The DoD Liveware Survey has been progressing rapidly. Many new Human Systems Integration (HSI) technologies have been added during the past two months. However, there are still many important HSI technologies not described in the database. For this reason, the sponsor, Mr. Mike Pearce of OASD(FM&P)/R&R(TFM) HSI office, and program manager, Dr. Mona Crissey, request that owners, developers, and major users of HSI technologies participate in the near future. The deadline to be listed in the March 1993 Liveware Catalog is January 31, 1993. The catalog will include all United States inputs, plus those of the other member nations of the NATO Liveware Research Study Group (RSG.21).

Participation to date is summarized in Table 1. The Training domain has had the greatest number (197) of programs listed. Human Factors Engineering has the second largest participation, with 109 programs as of December 3, 1992. The lowest participation is in the Health Hazards and Safety domains, but there are still 45 and 62 "hits", respectively. Participation by DoD Service shows the Air Force and Army running neck and neck with 59 and 51 technologies, respectively, while the Navy/Marine Corps has 29 technologies listed. The showing from Industry is quite good, with 59 technologies listed.

One of the greatest challenges faced by Liveware technologies is to integrate domain issues with each other domain, and with system acquisition issues. Translating across domain boundaries and with issues of system cost, schedule, and performance, are among the most difficult and desirable capabilities Liveware tool can possess. The NATO RSG.21 definition for Integration that was included in the Liveware survey defines the Integration as "The iterative process by which hardware, software, and manpower, personnel, training, safety, health hazard, and human factors engineering components are combined to create a system." Of the 318 technologies listed in the survey database, 77 state that they achieve integration. Table 2 presents number of technologies claiming they achieve integration by the number of Liveware domains they address. Of the 77 integrative technologies 26 are purported to address all domains. These integrative technologies which address all domains include the following: the Air Force Lessons Learned database, MANPRINT Test and Evaluation Methodology, Isoperformance Methodology, Aircraft Mishap Prevention, Systems Analysis of Integrated Networks of Tasks, CDRL Maker, and Design Evaluation for Personnel, Training, and Human Factors (DEPTH). While some of these have data from all domains, many do not actively make trade-offs across all domains, or enable trades between system requirements and the various HSI domains. Further validation of each submission is in progress to describe the degree these technologies will facilitate integration and help communicate iteratively between each domain and system acquisition issues.

To obtain a survey or further information, contact Dr. Mona Crissey at Department of the Army, Chief, ARL-HRED-STRICOM Field Element, ATTN: AMSRL-HR-MT (Dr. Mona Crissey), 12350 Research Parkway, Orlando, FL 32826-3276; (407) 380-4356, DSN: 960-4356, FAX: (407) 381-4201, E-mail: CrisseyM@Orlando-EMH3.Army.MIL. She is the Liveware Program Manager.

Or contact Frank C. Gentner at AL/CFH/CSERIAC, Wright-Patterson AFB, OH 45433-6573, (513) 255-4842, DSN: 785-4842, FAX: (513) 255-4823, E-mail: FGentner@FALCON.AAMRL.AF.MIL. He is CSERIAC's senior technical analyst assisting in the Liveware study.

Table 2

LIVEWARE TECHNOLOGIES REPORTING INTEGRATION

NUMBER OF DOMAINS ADDRESSED BY EACH TECHNOLOGY	NUMBER OF PROGRAMS
0 & 1	11*
2	4
3	12
4	11
5	13
6	26
TOTAL	77

** These programs will need further analysis to determine how they can be integrative when they involve only one/no Liveware domain(s)*

Table 1

LIVEWARE SURVEY PARTICIPATION
BY SERVICE/INDUSTRY (As of December 3, 1992)

LIVEWARE DOMAIN	UNITED STATES AIR FORCE	ARMY	NAVY MARINES	OTHER GOV'T	INDUSTRY	UNIVERSITIES & OTHER	TOTAL BY DOMAIN
MANPOWER	24	26	8	3	33	14	108
PERSONNEL	18	26	5	3	29	21	102
TRAINING	38	36	21	10	54	38	197
SAFETY	12	9	7	1	24	9	62
HEALTH HAZARDS	9	10	5	18	0	3	45
HUMAN FACTORS ENGINEERING	19	24	7	31	3	25	109
INTEGRATION (2 or more)	14	9	9	3	27	15	77
Number Programs in Database	59	51	29	12	59	108	318

Note: Each technology can impact more than one domain

Armstrong Laboratory Colloquium Series

Computational Models of Human Performance

Christopher D. Wickens

Editors note: Following is an abstract based on Dr. Wicken's presentation as the fifth speaker in the Armstrong Laboratory Colloquium Series: The Human Computer Interface. Dr. Aaron W. "Ron" Schopper, former Chief of Technical Services & Analyses at CSERIAC, prepared this abstract.

There is continuing pressure within the human factors profession to justify its presence in the system design process. Because the human factors engineer typically relies on HFE principles (and frequently cannot provide actual "numbers" with which he can assert the gains or advantages of applying these principles) he often finds himself at a disadvantage vis-a-vis both his engineering peers and those responsible for cost accounting, particularly in a resource-competitive environment. In an effort to combat this disadvantage, the human factors engineer must have a means of developing "numbers" from appropriate computational models.

There have been advances in computational human performance modeling in two human factors domains: workload prediction and display layout. Within each are identified the model parameters that can be quantified easily and those wherein major challenges to quantification remain. Also cited is the validation undertaken to date.

Workload Prediction

In the first domain, the question to be asked is "What quantifiable characteristics of a set of tasks contribute to the prediction of when performance will break down in multiple task situations—when the task demand exceeds the resource supply?" While a simple and logical starting point for such a model (and an easily quantifiable one) is to tally the number of tasks performed per unit time, this approach lacks an estimate of task demands. The added difficulty of a task may vary independently of the time required to perform it. The results of research previously undertaken at Illinois (Wickens, Larish & Contorer, 1989; Sarno & Wickens, 1991) have shown that the incorporation of task demand level into a time-line model will bring the variance accounted for in predicting differences in performance of a set of multiple task configurations from near zero up to around 60 percent. However, the issue of how to quantify task demands (other than by their time requirements) remains a challenge.

A second feature missing from a quantitative-computational model is the ability to account for the amount of interference that may occur among certain tasks because of their similarity. Several factors influence the structural similarity between tasks, i.e., the extent to which they share the same stage of processing (perceptual, cognitive, or both), the same perceptual modality (auditory, visual, or both), and/or the same processing code (verbal/linguistic or spatial).

Evidence suggests that people deal with overload situations by adopting fairly simple rules of task-shedding. Hence a final feature of a computational workload model should account for how people schedule, shed, or add tasks when workload becomes excessive. The real challenge to computational models will be to identify (and predict) the level of demand at which concurrent task performance "catastrophically" regresses to sequential performance.

Table 1 summarizes the present status of efforts to develop computational models of multiple task performance, the promising avenues for quantification, and the challenges.

Table 1

Present Status of Computational Models of Multiple Task Performance

FACTOR	CHALLENGE	SOURCE
Time Line	Task Time Data	Boeing, HOS
Demand Level	Task Effort Data (Table Lookup)	McCracken/Aldrich
Multiple Resources (Similarity-based Interference)	Simple Conflict Matrix	WINDEX, CREWCUT
Scheduling/Shedding	Simple Rules and Algorithms	Z-scheduler/CREWCUT

Display Layout Analysis

A good computational model should be able to provide the display panel designer with information regarding the costs and benefits of positioning different sources of information at different locations.

To obtain information from a visual display, obviously it should appear within foveal vision. Whereas this represents a trivially simple layout problem when there is but one display, it becomes less so as the number of displays increases. The need to foveate is a design "force" (based on the economy of human information processing) whereby two displays are attracted toward each other with a force that is proportional to the importance (I) of the two displays (importance being related to the frequency of use) and their distance apart (D, degrees of visual angle), as reflected in the formula $F=D(I1+I2)$. By averaging these forces across all pairs of a display ensemble, an overall "figure of merit" can be derived.

Five principles of human information processing "drive" this desire for proximity between two displays and suggest, where possible, the quantitative basis that could underlie a computational model of these forces. These five principles follow.

Information Access Effort

The first accommodates visual scanning. Display pairs located quite close together (within a few degrees) can both be consulted without scanning. This "No Scan Region" is often equal to the foveal angle of regard, but also varies as a function of the visual angle with which the symbols need to be resolved. It will be larger if motion perception is required than if the task calls for symbol classification. When two displays are separated by an angle that exceeds the no-scan region (so that a visual scan or saccade is necessary), evidence suggests that the time and effort required for longer scans are not much greater than for short scans, a region that Sanders (1970) has labeled the "eye field." However, if the separation is greater than an angle which the eye can easily scan without head movement, then head movement will add an extra penalty of effort. This penalty grows in magnitude proportional to its distance, since, unlike visual saccades, head movements are not ballistic.

Search Uncertainty

In an open field between two information sources, changes in the visual angle between information sources have little effect on performance within the eye field. However, in a cluttered display, there is an increasing penalty with longer distances. It becomes progressively more difficult to locate the target destination as the intervening field is filled with greater "clutter." Eye movements are also initiated more slowly if their destination is uncertain. Recent work by Andre & Wickens (1991) has proposed the concept of a linear "object distance" penalty which may be computed by the number of visual objects that must be scanned from origin to destination. Alternatively, assuming a homogenous density of display objects across the scanned space, this penalty may be considered a linearly increasing function of metric distance.

Confusion

When one is scanning across a multi-element display, the effect of an "attractor force" would be to bring all displayed elements to a single, superimposed location—a clearly counterproductive consequence. Hence, a "repeller" force of constant magnitude between all displays must be incorporated that will increase as a function of their proximity beyond a certain threshold. Such a force would serve to keep displays separated unless their attraction is extremely strong (as is the case with head-up displays).

Relatedness

The true superimposition of images (as in the head-up display or "HUD") appears to be a bad idea. However, much of the information presented on a HUD has a special quality that makes superimposition desirable; the information is said to be conformal with the world beyond. The intent of the display is to better allow the pilot to integrate these two sources of superimposed information. This fourth "moderator" is that sources that are related to each other (or to be integrated in a common task) should experience a stronger mutually attracting force. Two or more information sources that need to be mentally integrated should be displayed with close "perceptual proximity." Information sources that are to be distinct from each other should be displayed more separately. For the current discussion, the measure of perceptual or display proximity is that directly measured by object distance. However, the precise definition of task proximity is somewhat more difficult to achieve. There are certain circumstances where two indicators must clearly be integrated or compared, for example a command and actual air speed indicator. But there may be other circumstances when two indicators are related to the same task but do not need to be integrated, for example, cross checks between heading and altitude during a coordinated aircraft turn. Notwithstanding this uncertainty, the important attraction force of task relatedness has been demonstrated in previous research undertaken by Andre (Andre & Wickens, 1991).

S-R Compatibility

The location (or relocation) of any display on a multi-element panel should consider the spatial relation to the control element that drives that display's behavior. This consideration may conveniently be broken into two subforces related to Colocation and Congruence. Colocation is simply an attractor force that pulls a display and its associated control together. The principle of congruence dictates that the spatial ordering (e.g., left-right, top-bottom) of a set of displays should be congruent with the ordering of the corresponding control set. Earlier work with Andre

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showed that the set may be congruent, acongruent, or incongruent, that the magnitude of the effect is related to the cosine of the angle between the control and its corresponding display (Andre & Wickens, 1991), and that there is at least some evidence that the relative strength of congruence may be greater than that of colocation (Andre & Wickens, 1991; Andre, Haskell, & Wickens, 1991).

Table 2 presents a summary of the factors identified to influence display layout, and the quantification challenges they present.

The host of factors and their interactions which should ultimately be incorporated in a full-blown computational model may appear overwhelming; however, it may be (as is often the case in psychology) that a few well chosen and carefully, but simply, implemented components can predict a substantial variance in human performance. Such would, indeed, be a great step forward for the human factors engineering profession. ●

Christopher D. Wickens, Ph.D., is a Professor of Psychology and Head of the Aviation Research Laboratory, University of Illinois, Champaign, IL.

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Table 2

Display Layout Model Factors	
FACTORS	**CHALLENGES**
1. Importance	Frequency or criticality?
2. Information Access Effort	Peripheral resolution with objects—size, motion, color. Head-field angle.
3. Search Uncertainty	Definition of "objects" inducing clutter. Spatial frequency analysis?
4. Confusion	How is confusion modulated by distinctiveness of color?
5. Relatedness	Task or structure? Quantification issues.
6. S-R Compatibility	Colocation versus congruence? Dedicated versus reach control? Defining array membership.

Continued from page 12

nization is a major driver of cognitive workload, but our workload approach goes beyond the display side to the mental processing and response side; this is where the Multiple Resource Theory comes into play. The issue of quantifying workload from a multiple resource perspective is very challenging, but the rewards could be great.

CSERIAC: I would like to pose a hypothetical question. What if you were to receive a large block of funding to tackle some research problem, which you feel has been neglected? Where would you direct these resources?

Dr. Wickens: Well, I think one area which continues to need a tremendous amount of research is the so-called "pucker factor"—the effect of stress on human performance. That has been a very research-poor area, in part due to the ethical contstraints in doing stress research. So, generous financial help alone would not be sufficient. We need either a release from some of the constraints in doing this type of research, or to come up with some clever methods for doing research on human performance in contexts where stress naturally occurs—in the field, such as during Desert Storm operations.

My *personal* interests at this point go strongly to the area of human factors of visualization of very complex images. What I see is a mismatch between what computer technology gives us to create complex visual images for scientific visualization, and what human factors and human perception tell us about the best way to represent the data. The technology has exceeded our capability to define principles for what is good and bad in the design of such systems. This is the other area where I would put a hypothetical research grant to work. ●

Armstrong Laboratory Colloquium Series

A Conversation With Chris Wickens

Reuben L. Hann, PhD.

Editor's note: The following is an edited transcript of a conversation with Dr. Christopher Wickens, University of Illinois, who had just made a presentation as the fifth speaker in the Armstrong Laboratory Colloquium Series: The Human-Computer Interface. The interviewer was Dr. Lew Hann, CSERIAC COTR.

CSERIAC: I understand you served on the National Research Council Committee on Human Factors. What kinds of issues did you deal with?

Dr. Wickens: There were two functions. One was to set the agenda for where we thought human factors ought to be headed. That's why the council is sponsored by places like NSF, Armstrong Lab, ONR, OSR, and the Army HEL. They were looking to us to voice where the profession ought to be moving, and therefore to give them guidance on where research programs should focus. The other function was to set up subcommittees within our group, which were tasked by either an outside agency or our own agenda, to look in depth at a particular issue. Some topics include Mental Models in Computer Systems, the current state of Anthropometric Modeling, and one about to start in the area of Virtual Reality Technology. Beverly Huey and I are finishing a report (to be published as a book) in the area of Workload Transitions. That is, what happens when a team of operators, such as a nuclear power crew, that spends the majority of its time doing very low workload tasks, suddenly has to mobilize into action, transitioning into a high workload mode. How does that team function? What factors are important for good team performance?

CSERIAC: A question I pose to each of the speakers interviewed: Do you have any thoughts on how we in the human factors community could better "sell" our discipline in terms of improved return-on-investment?

Dr. Wickens: I've thought a lot about it. Just today I was discussing how the FAA wants to see their investment in the *National Plan for Human Factors* reduce accident rates. This is, extremely difficult to demonstrate, because human factors input to any process is only one of several. You don't know exactly what breaks down when there is an accident, or what *doesn't* break down when accidents are saved.

"I have some frustration with the mainstream psychology community because of how reluctant many of them are to examine their theories in relatively complex environments."

A lot of it simply comes from the user community, and one thing we are seeing, as human factors get marketed more into consumer products, is expressed satisfaction with how well human-engineered a particular system—such as the Apple Macintosh computer—is. I think that the Macintosh and the Xerox Star have gone a long way toward validating the good application of human factors with a tangible metric, that is, sales and marketing. This is the positive approach. In the negative approach, you point to the current state of systems that haven't been human factored and show how bad they really are. A lot of good case studies involve poor aircraft design, where you can point to an accident in which poor human factors was a likely cause. Also, you can point to many human-computer systems which are horrible to use, and you can argue about why. The problem beyond that is convincing people that human factors input is more than just common sense intuition.

CSERIAC: And, of course, good human factors is always "obvious" when viewed after the fact.

Dr. Wickens: Exactly. And there you can point to some of the challenges I discussed today. That is, you ask, which principle are you going to adhere to? You can't have both. You can have A and not B or B and not A. That is the kind of "intuitive" issues you can't answer on the basis of intuition. You need human factors research to tell you what is most important.

CSERIAC: In a recent issue of *Gateway*, Dr. Tony Cacioppo of Wright State University described the human factors program at that institution. His program emphasizes the engineering aspect of human factors engineering. What is the situation at University of Illinois?

Dr. Wickens: It's very much a hybrid approach. Formally, its called Engineering Psychology, reflecting its origins in the psychology department, with a close affiliation with the Aviation Research Lab. Engineering has since joined in, so now there are two human factors programs, each with its own curriculum requirement. But there is a lot of cross-fertilization, with students from each program taking courses in the other. The emphasis of both programs is on human interaction with complex systems. We've had success

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with this two-pronged approach.

CSERIAC: This sounds a lot like the system at Wright State. And, as Dr. Cacioppo has pointed out, there is a decided advantage in their graduate's ability to communicate with the engineering community. After all, this is who really needs the information.

Dr. Wickens: Yes, and at the same time, the engineering community gives the psychology community a lot of applied contexts in which they should test their theories—in a way many psychologists are reluctant to do. I have some frustration with the mainstream psychology community, because of how reluctant many of them are to examine their theories in relatively complex environments. Yes, it's risky, but the payoffs are high.

CSERIAC: I recently heard a presentation in which the investigator casually mentioned that he had taken a "cognitive workload" measure as part of his data collection. It was treated as though it was something which is now routine. I used to work in this area and remember how difficult the enterprise was, so, unless there has been a lot of progress recently, it seems to me this was all a bit naive. What is your assessment of the status of our ability to measure cognitive workload?

Dr. Wickens: I admit our capability for measuring cognitive workload probably is not much better now. We have made some progress *predicting* cognitive workload, which is different from *measuring* workload. We know more about some fundamental characteristics that drive workload in the cognitive domain, such as working memory demand, number of transformations, and so forth.

CSERIAC: Are you still using and developing your Multiple Resource Theory?

Dr. Wickens: Yes. I did not have time to go into it during my presentation, but it's really the other side of my research area. Of course, display orga-

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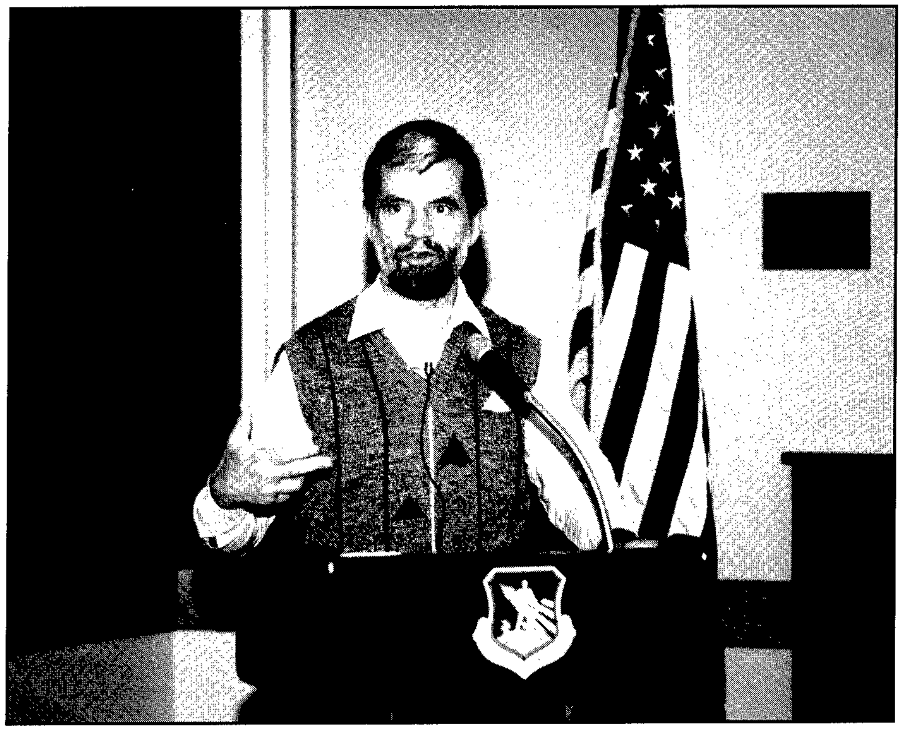
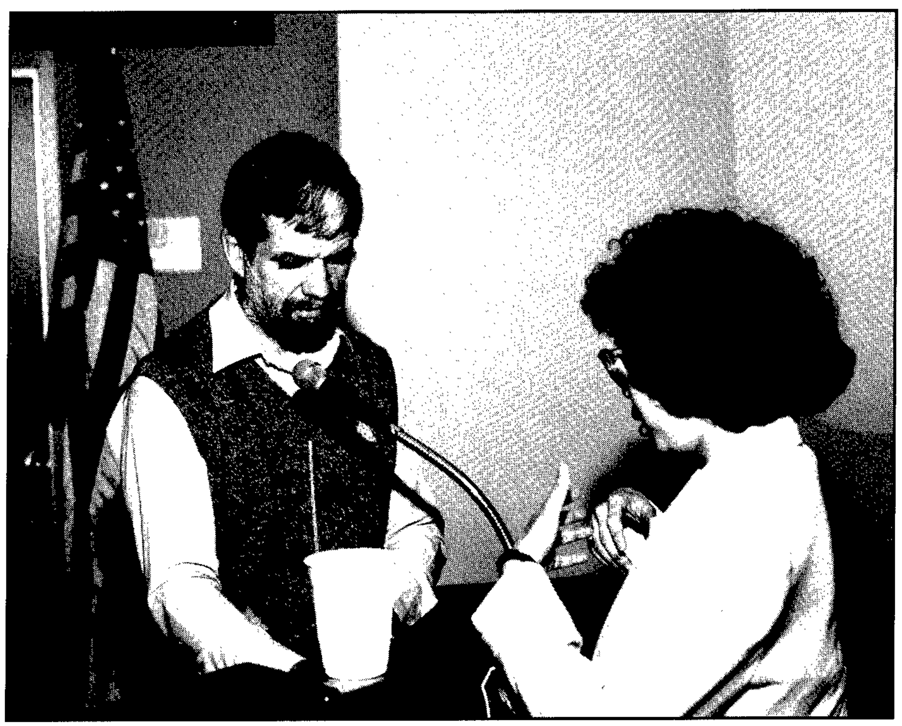
Scenes from the Armstrong Laboratory Colloquium Series:



Dr. Christopher Wickens, University of Illinois, spoke on computational models of human performance.



Following his lecture, Dr. Wickens entertained questions from many of the attendees.

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David P. Harding

Jack™ is a powerful human factors design and ergonomics visualization software package. It is the product of a continuous research effort dating back to the late 1970's. The *Jack* program's original objective was the development of a realistic, computer-based human model for the simulation of human performance in enclosed spaces. While the system was initially used for analysis of military and space vehicles, its flexible nature makes it applicable in many commercial and industrial situations. *Jack* played an important role in the human factors design of a new line of earth-moving equipment developed by John Deere & Co. Numerous U.S. government agencies, such as NASA and the Army Research Office, as well as several commercial entities have supported this project. As the *Jack* program evolved, its value to industrial designers, architects, and animators became apparent. In 1991, the University of Pennsylvania decided to market *Jack* directly to the public. Since that time, hundreds of inquiries about *Jack* have come in from around the globe.

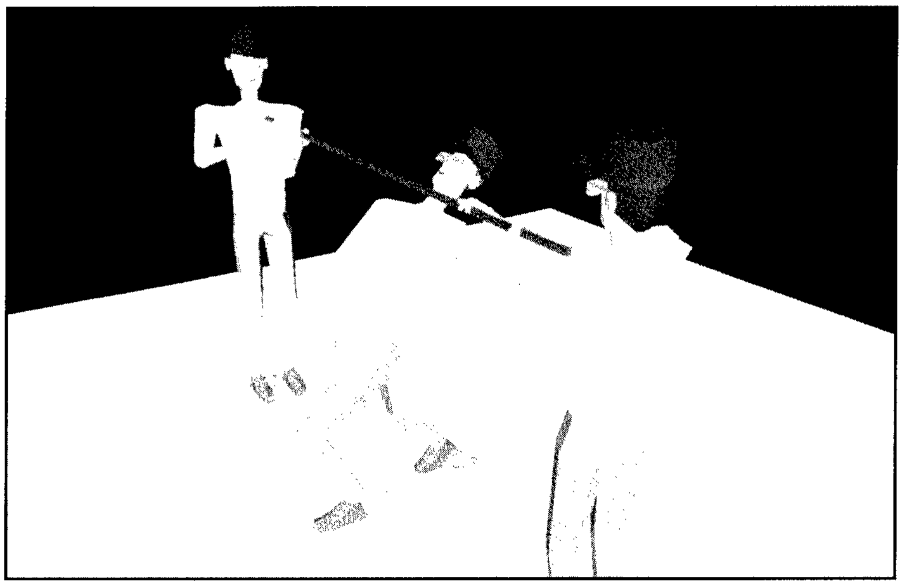


Figure 1. Three human figures doing the limbo. The flexible human torso and balance constraints in Jack let the users visualize realistic human performance in their designs.

Jack enables the analyst or designer to perform several types of computer-based human factors analyses in three dimensions (see Fig. 1). These analyses include tests of how different-sized humans fit in a system, whether the human will be able to reach controls and mechanisms, the extent of the human's field of view, and joint torque modeling under different static loading conditions. The U.S. Army and the NASA Ames Research Center have jointly used *Jack* to simulate display legibility in a military helicopter cockpit. The designer can place a human figure into a simulated cockpit to test whether the operator can reach or see a control panel. A window appears on the display that shows what the controls look like from the human figure's vantage point. In this way, *Jack* can answer such critical design questions as: "What can the pilot see?" and "How accessible are controls?"

Traditionally, analyses such as these had to be performed using paper and pencil or by placing crude two-dimensional mannequins on blueprint drawings of the system being tested. In either case, blueprints had to be tediously redrawn each time a new design option or solution needed to be evaluated. Many problems were missed because the analyst or designer never really got the whole picture until an expensive mock-up of the system was built. By the time a mock-up was built, design options and solutions were limited because of the difficulty and expense of rebuilding the mockup.

By using *Jack*, the designer can take easy-to-alter, computer-based designs of the system, import them into *Jack*, and perform human factors analyses in three dimensions. This allows the designer to better identify problem areas early in the design process. According to Dr. Norman I. Badler, Professor of Computer and Information Science, who created *Jack*, "By building computer models early in the design cycle, we avoid having to build physical mock-ups of the actual situation or environment. This does not mean that mock-ups are useless, but early on, the designer may not know where people and items will be placed inside the environment, and it's much more flexible to have a computer graphics model that can be changed, instead of going to a machine shop and having them retool a portion of the mock-up."

Jack's wide array of powerful features gives the user the tools to visual-

Continued on page 14

ize, manipulate, animate, and render human figures. The biomechanically reasonable human figure with 88 joints and a flexible spine lends realism to analyses, and the flexible anthropometry features give the user complete control of anthropometry specification. The default human figure is based on Society of Automotive Engineers anthropometric data, but the user may specify other data bases, such as the ANSUR data base, or create custom data, via spreadsheet (see Fig. 2), to meet application-specific needs. Simple mouse movements allow the user to intuitively manipulate the human figure and view it and its virtual environment, from any position in space. The system's sophisticated space and view analyses provide an accurate picture of what a human would see, both from an externally viewed cone of vision, or through the human figure's "eyes." *Jack's* animation and rendering modules let the user generate highly persuasive simulations and presentations with realistic appearance (see Fig. 3). These versatile features make *Jack* useful in applications such as animation, architecture/interior design, aerospace/defense, agricultural and industrial equipment design, education and training, automotive design, factory ergonomics, furniture and appliance design, and medical and dental equipment design.

J*ack's* flexibility is enhanced by its ability to interface with many popular CAD, animation, and rendering software packages. Currently, *Jack* runs only on Silicon Graphics workstations, but versions for IBM, SUN, and HP/Apollo workstations should be available within 12 to 18 months. The University of Pennsylvania provides training as part of the purchase price of the system. Training workshops are also offered on a quarterly basis at the University. Potential users need not have formal programming experience or computer science training, but general familiarity with engineering software packages is helpful. The product is available to both US and international organizations. Substantial discounts are provided to the US Government, its contractors, and educational institutions.

For further information about *Jack*, please contact David Harding at the University of Pennsylvania, Center for Technology Transfer, 3700 Market Street, Suite 300, Philadelphia, PA, 19104-3147. Telephone: (215) 898-9585, Fax: (215) 898-9519, Email: harding@a1.relay.upenn.edu. ●

David Harding is the Jack Product Manager at the University of Pennsylvania's Center for Technology Transfer, Philadelphia, PA.

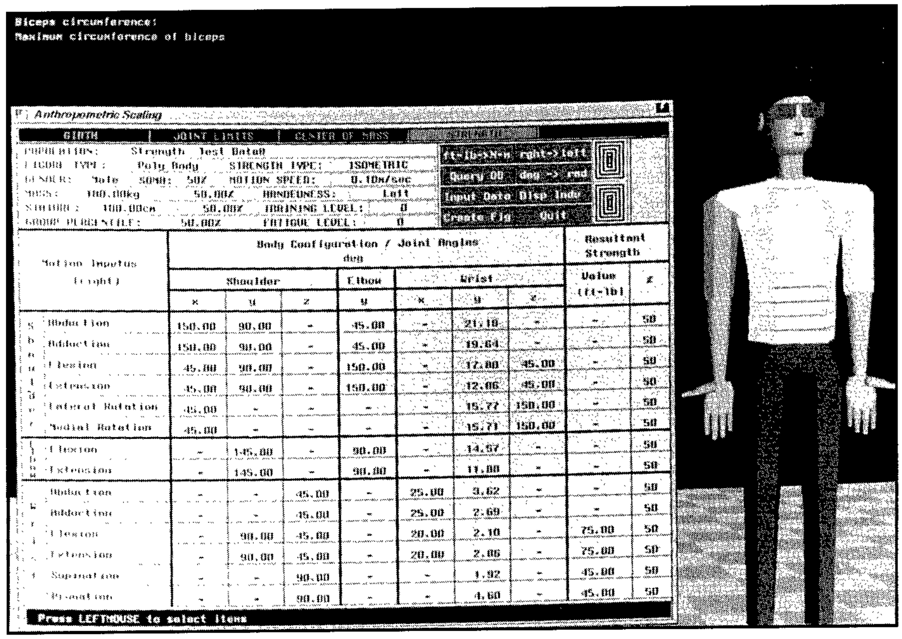


Figure 2. Human figure next to a spreadsheet. The interactive Spreadsheet Anthropometric Scaling System gives the user the flexibility to vary anthropometric data while concurrently viewing changes to the human figure.

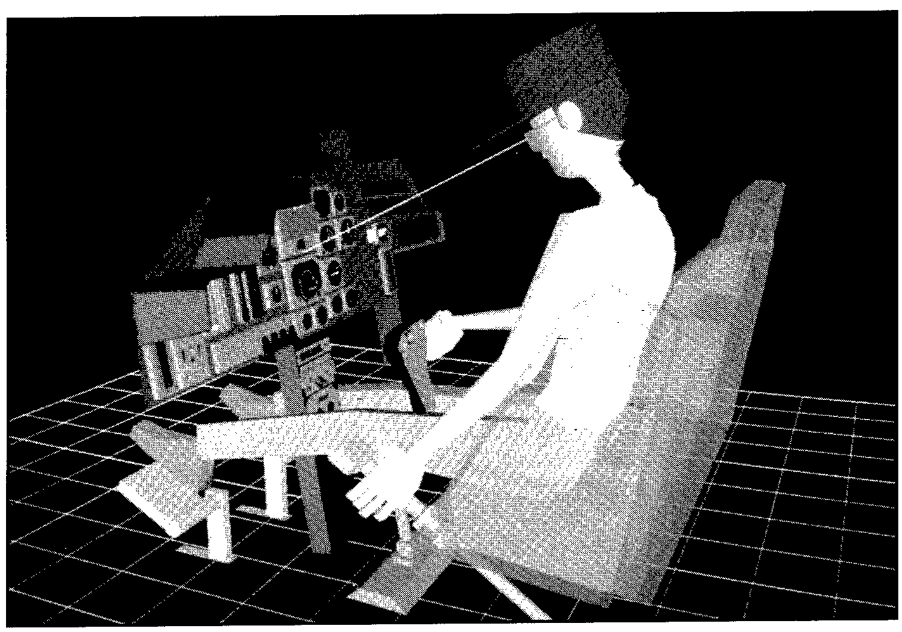
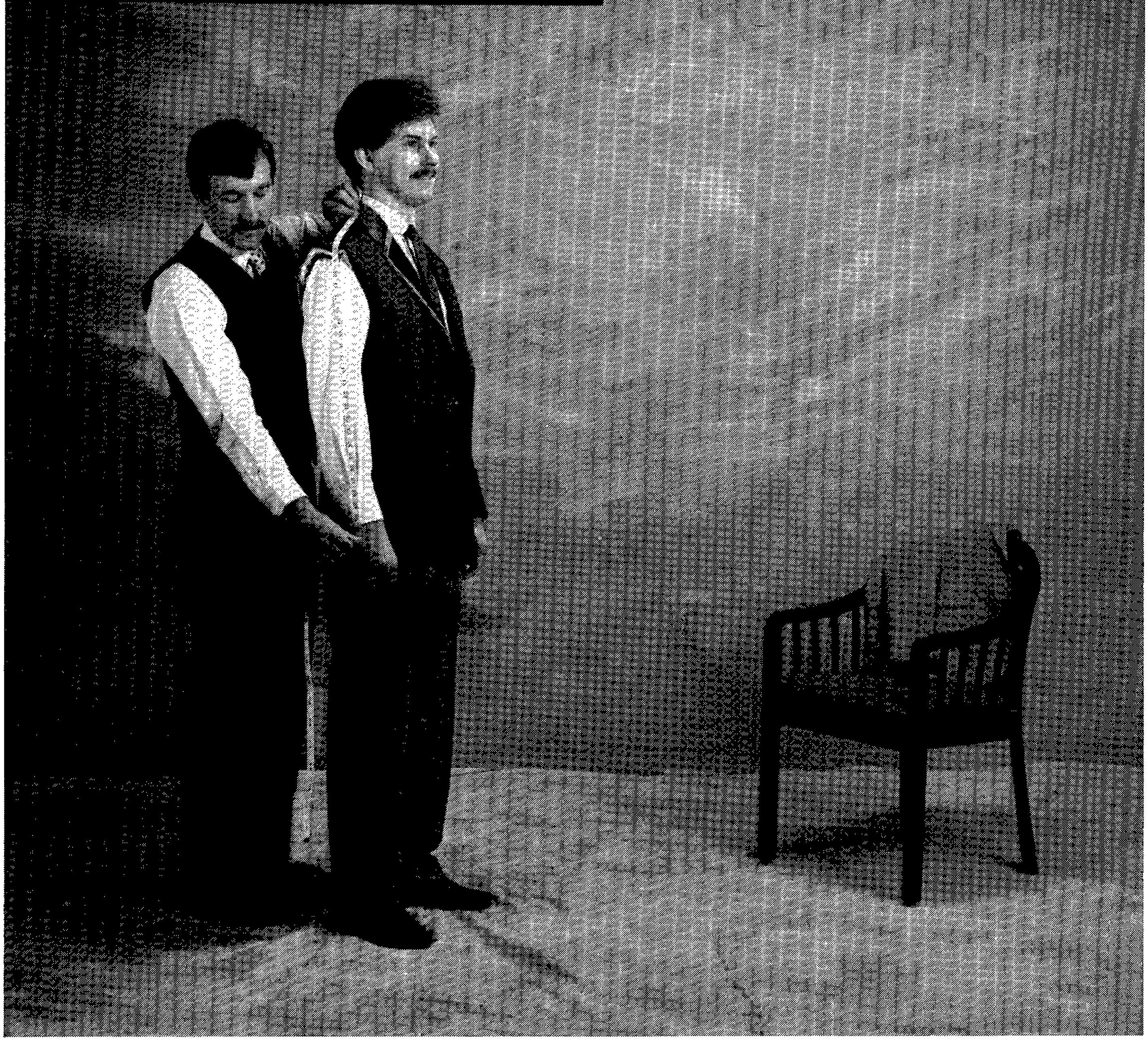


Figure 3. Human figure in cockpit reach, view, and fit analysis. Jack lets the user constrain foot and hand positions as well as view goals while varying the population percentile to assess important ergonomic factors.

THE PERFECT FIT!



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Government
Technical Manager ....(513) 255-8821

Associate Director: Dr. Lawrence D. Howell; *Government Technical Manager:* Dr. Reuben L. Hann; *Government Technical Director:* Dr. Kenneth R. Boff.

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